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Montessori Mathematics Curriculum and Lower Elementary Students Understanding of Length Measurement

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An Action Research Project

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Abstract

The intent of this action research project was to determine to what extent the Montessori Mathematics curriculum support lower elementary students' understanding of length measurement. The research took place in a private Montessori school classroom with first and second-grade students. There were 22 students in the class, 11 first graders, and 11 second-graders. Data was collected through a pre and post-test, field notes, and observations. The students also kept a journal and performed self-assessments. Photographs were taken to record the students' use of different measurement tools. Children's literature about length measurement was read and discussed with the students. The data indicated that students in first and second grade have a difficult time understanding length measurement, particularly reading standard measurement tools. While the Montessori mathematics curriculum supports student understanding of length measurement, it is clear that some of the students need to have other opportunities using nonstandard tools. Overall, the Montessori mathematics curriculum supported students understanding of length measurement. The findings suggest that additional materials need to be introduced in the classroom for students to utilize, and many opportunities are available to measure with nonstandard tools to completely understand measurement and length.

Keywords: measurement, length, mathematics, Montessori

As educators, we attempt to support our students understanding of all subject matters. Students are required to take tests meeting California Common Core State Standards (California State Board of Education, 2013). As Montessorians, we seek to determine if our curriculum will address these new standards. California Common Core State Standards: Mathematics, (CACCSS), require students to have core knowledge in understanding measurement (Common Core State Standards: California, p.2). Changes made for testing student knowledge encouraged me to evaluate the students' understanding, beginning with the math curriculum. The organization has not determined if we will utilize the CACCSS testing. It is necessary for us to review the standards.

In conversation with the elementary teachers, they have noticed that the lower elementary students have a difficult time understanding length measurement. The students do not have a clear, concrete understanding of measurement. Students use the Montessori mathematics materials and a math textbook, which is one grade level above their current grade, to support the Montessori math curriculum. I evaluated our classroom materials used to teach how to measure and found that primarily, student's practices came from the directions in the textbook used in the classroom.

I examined the literature on how students learned length measurement. Castle & Needham, (2007) wrote that children in first grade should focus on "what it means to measure rather than how to measure" (p. 220). Students needing to concentrate on the meaning of measuring rather than measuring itself, led me to examine how we taught students this concept. First graders appear to have had most of their practices of measurement through the use of their textbook. Questions such as "how big is something", or "how much bigger is"… were typical. Students showed interest in

measuring with different measurement tools other than a ruler. Teachers observed students having difficulty understanding how to use a ruler, where to start, and how to read the numbers. When students used nonstandard tools, such as paper clips, links, blocks and Montessori sensorial material they were excited about measuring different objects. Clements (1999) suggests that students require experiences with standard and nonstandard tools for measurement (p. 5). Reading quality children's books on the concept of measuring was suggested as another way of stimulating conversation between the student and teacher in understanding measurement (Bintz, et al, 2011; Castle & Needham, 2007).

I have decided to examine one curriculum area, measuring length, to determine if the Montessori mathematics curriculum meets the standards. Do the students in our school have the background that will allow them to understand what it means to measure? Will they be able to measure using standard and nonstandard tools and be able to articulate what the process of measuring is? What about measuring in customary units (inches, feet, and yards), and in using the metric system (millimeters, centimeters, and meters)?

I chose to conduct my research in one of our lower elementary classrooms. The class consists of 11 first-grade students and 11 second-grade students. There are 8 boys and 14 girls. The school is private, and there are 80 elementary students from first through sixth grade. As the Director of the school, I am not responsible for the daily instruction of curriculum to the students. I consulted with the two teachers in the classroom where the action research project occurred, and they both consented to collect data through observations and field notes for the study. I administered a pretest and post-

test and used the results from the Standford Achievement Test given last school year of the students that are now in second grade. First-grade students did not take the Standford Achievement Test last school year. Students were requested to keep a journal when working with measuring to record their exercises and assess their understanding of the concept of length, utilizing the tools they currently have available to them in the classroom. Photographs were taken to show how the students are using different types of instruments to measure with and to capture how they work together in gaining their data.

The goal of this action research project is to answer the question: to what extent does the Montessori Mathematics curriculum support lower elementary Montessori students' understanding of length measurement?

Review of Literature

The California Common Core State Standards: Mathematic (CCSSM) (2013) requires teachers to prepare students to meet domain specific requirements. In grades K–3, each grade level has a standard for Measurement and Data. The standards for Kindergarten include describing and comparing measurable attributes. First grade standards include "measuring lengths indirectly and by iterating length units" (CCSSM, 2013, p. 17). Second grade standards include measuring and estimating using standard units. Third grade standards include solving problems that involve measurement and estimation. This study will focus on the above standards and will include student's use of different types of measuring tools for both standard units and the metric system. Students need to have core knowledge in length measurement in preparation for further education (CCSSM, 2013, p. 2).

Research completed by Castle & Needham (2007) involving 16 first-grade students, found that first grade students require an understanding of transitivity, unit iteration, and conservation in order to understand length measurement (p. 216). Based on the study, first-grade students showed a lack of conservation and understanding units when required to use measurement tools and measurement terminology. Understanding of the relationship between numbers and length happens between the ages of six and eight (Castle & Needham, 2007, p. 220). The findings of this study are that students in first grade should focus on what measuring means instead of how to use a measurement tool. Children's literature about measurement encourages discussion amongst the students and teacher for understanding length measurement.

Bintz, Moore, Wright, & Dempsey (2011) were prompted to do research on measurement as a result of Dempsey's teaching experiences with her fourth-grade student's lack of understanding length measurement. This study involved 20 fourth-grade students. Quality literature was used in this study to develop activities in evaluating students understanding of length measurement. The researchers found that students need to know how to use different types of measuring tools, such as standard rulers, yardsticks, or meter sticks. Nonstandard measurement tools using body parts, such as the thumb and hand, is another way to measure. The students had difficulties understanding how to use the standard tools. A particular focus of the problems they noticed was fractional units. Students were confused using nonstandard tools because nonstandard tools do not give precise measurement. As stated in Drake (2014), reading fractional units on a ruler is a challenge for many educators to teach students. Included in the study is a list "Suggested Children's Literature for Teaching Measurement" (Drake, 2014, p. 62).

McDonough & Sullivan (2011) focused their research on students in their first three years of school. The aim of this study was to examine students' learning of length measurement and to present teachers with ideas on how to best teach students length measurement. They found that students in each grade focused on a different understanding involved in measurement. First-year students have shown that they can compare and order. Second-year students need direct lessons on iterating units for understanding length measurement, and third-year student require direct lessons and experiences in measuring with standard units. Use of standard tools (e.g., ruler) and nonstandard tools (e.g., paper clips, string) were tools used for this research. Researchers suggested that students need structured lessons by the teacher for understanding length concepts (Clements, 1999; Drake, 2014; McDonough & Sullivan, 2011). Students need to have acquired cognitive abilities of comparison, conservation and transitivity (McDonough & Sullivan, 2011).

Similarly, Drake (2014) studied the importance of different types of rulers for understanding length measurement. Research has shown that regardless of what type of measurement system students learn, students have difficulty understanding length measurement. Learning to read a ruler is a cornerstone of grasping measurement. Both younger and older students have difficulty in understanding where to begin measuring on the ruler; start at the end point or the symbol of 1? When measuring with a ruler, the results are not always in whole numbers. The sequence of introducing the use of a ruler is necessary. Students need many opportunities to measure different objects resulting in whole numbers before they can understand the concept of units and fractional units.

According to Drake (2014), "Students not only have to understand the concept of a unit [something is long] but that we use different units in different circumstances" (p. 32).

Further research conducted by Clements (1999), suggested that students require experiences with standard and nonstandard tools for measurement. Clement (1999) wrote, "Piagetians claimed that children achieve an understanding of measurement only at about age 9" (p. 5). In contrast, Castle & Needham (2007) wrote that understanding occurs between six and eight years of age (p. 220). It is beneficial for students to design their own rulers for them to construct an understanding of measurement. People of all cultures measure with non-standard tools as a part of everyday life, which is why non-standard tools are important.

Robertson (2014) wrote about the importance of understanding standard units and universally having the same standards for understanding measurement, particularly in the context of the exchange of goods with other countries. In communicating about measurement, precision and exactness is relevant to understanding universal standards.

In addition to elementary students learning about measurement, Ashbrook (2014) revealed that preschool aged children learn about standard lengths of a unit by using unit blocks. When children use unit blocks, they are introduced to a comparison of length when they build roads or structures. Understanding common terms of what is long or short is important when building with unit blocks (Ashbrook, 2014).

In an earlier article written by Ashbrook (2006), children have confusion on length measurement when viewing pictures of animals or buildings that are not shown to scale. One strategy to improve understanding of the numbers on a ruler is to use nonstandard tools, such as coins and positioning them side-by-side (Ashbrook, 2006, p.

44). Another strategy for teaching length measurement is through the Montessori curriculum (Aaquist, 2012).

There have been alignments with Common Core Standards and Montessori curriculum to address the teaching of length measurement. Aaquist (2012) completed an alignment of the Montessori Mathematics curriculum and the CCSSM. Aaquist aligns the measurement domain by describing the concept and materials to be used. The materials for the alignment are different types of measuring tools, such as rulers, yardsticks, meter stick, and measuring tape. The use of Montessori sensorial materials and grammar materials are also tools used for measurement.

With the adoption of the California Common Core State Standards: Mathematics (CCSSM) (2013), Montessori educators are called upon to evaluate the Montessori mathematics curriculum to ensure Montessori students gain an understanding of the domain requirements.

Based on the literature, students need to have the cognitive abilities to understand comparison, transitivity, unit iteration, and conservation (Castle & Needham, 2007; McDonough & Sullivan, 2011) in learning length measurement. Students need to be offered many opportunities to practice measuring the length of different objects with standard and nonstandard tools (Bintz, et al., 2011; Clements, 1999; Drake, 2014). It is also suggested that with the use of quality children's literature, students may increase their understanding of length measurement (Bintz, et al., 2011; Castle & Needham, 2007). Aaquist (2012) identified materials in the Montessori curriculum that supports the CCSSM, in particular, length measurement through the use of Montessori materials.

Methodology

The Action Research Project began on September 15, 2015 and ended October 23, 2015. Prior to beginning the research, the parents of the students in the classroom were given an Passive Consent Form allowing their child to participate in the Action Research Project. The two teachers in the classroom were given an Active Consent Form, agreeing to observe and collect data for the project. A pretest and post-test (See Appendix A), and a student questionnaire (See Appendix B) were prepared and submitted for approval. There were two teachers in the classroom; both agreed to participate in the research. The teachers observed and documented their observations of the students' work and the discussions they had with the students. There are 24 students in the classroom, consisting of 11 first-graders and 13 second-graders. One first-grade and one second-grade student opted-out. I am the researcher, but I do not teach in the classroom where the research was conducted. The research was extended an additional week as the pretest took two sessions to complete and there were some days that I, as the researcher, was unable to complete the scheduled sessions due to administrative responsibilities. Observational notes were recorded in a journal.

The research began by discussing the concept of measuring length. I asked students questions about their knowledge of what it means to measure and what type of tools could be used for measuring. Vocabulary used and reviewed in measuring was with customary units, such as inches and feet and with the metric measurements such as centimeter and meter. The students were presented a ruler, yardstick, and tape measure with both customary and metric markings on them. They were also shown the red rods, paperclips, and a pencil as nonstandard examples. The pretest was administered during

group time. The questions were read out loud, and students were asked to write their answers or draw a picture of the answer. There were three questions where the student could circle the answer if they chose. The students had a difficult time understanding how to answer the questions on paper, yet many were able to verbalize their responses. The test was re-administered two days later due to the students' difficulty in understanding how to respond to the test questions.

The pretest was re-administered on the second session. Upon completion of the pretest, *Measuring Penny* (Leedy, 2000) was read to the students. Students were encouraged to discuss the value in using different types of measuring tools and the many different things that can be measured. Students measured using standard (e.g. rulers, yardsticks and tape measure) and nonstandard tools (e.g. paper clips, connecting links, red rods, pencils, etc.).

The next step taken was reviewing how to read a ruler, yardstick and tape measure with the students at each session. The starting point of the ruler, yardstick, and the tape measure was indicated to the students. Each standard measuring tool has a different starting point based upon the format of the design. For example, one ruler had the words "start here" on it, while another ruler had a line showing the starting point. The students were shown how they could use multiple tools to measure if the object they were measuring was longer than the tool they initially selected.

At the third sessions, students were asked to journal their work with length measurement in a journal packet made from Montessori blue-lined cultural paper (See Appendix D). The students were requested to draw pictures of what they were measuring

and to write their answers. Journaling was used for students to show how and what they measured in picture form and writing, based on their skills.

Additional length measurement tools and command cards, which gave directions on what to measure and with what tools was supplemented to the already existing measurement shelf. The command cards used were from ETC Montessori and Lakeshore Learning.

Before each session, I reviewed the previous session's discussion and activities. On the sixth session, several students used the classroom computers to work on measurement activities available through a computer program. Students chose to use the computer rather than other measurement tools for one session.

Reading children's literature to the students started at the beginning of the second session. In addition to *Measuring Penny* and *How Big is a Foot* (Myller, 1991); *Beanstalk: The Measure of a Giant: A math adventure* (McCallum, 2006); and *Inch by Inch* (Lionni, 1995) were added. The use of children's literature was used to stimulate conversation and give a different perspective on the concept of length measurement.

In addition to observational field notes, photographs were taken throughout the research process to show how students measured objects, including each other, using standard and nonstandard tools (See Appendix C).

The use of observational data I collected, along with data collected from the two teachers, allowed for the decision of presentations on each session. Discussions held with the students and reviewing their journals were instrumental on learning the knowledge they had and acquired during the research process.

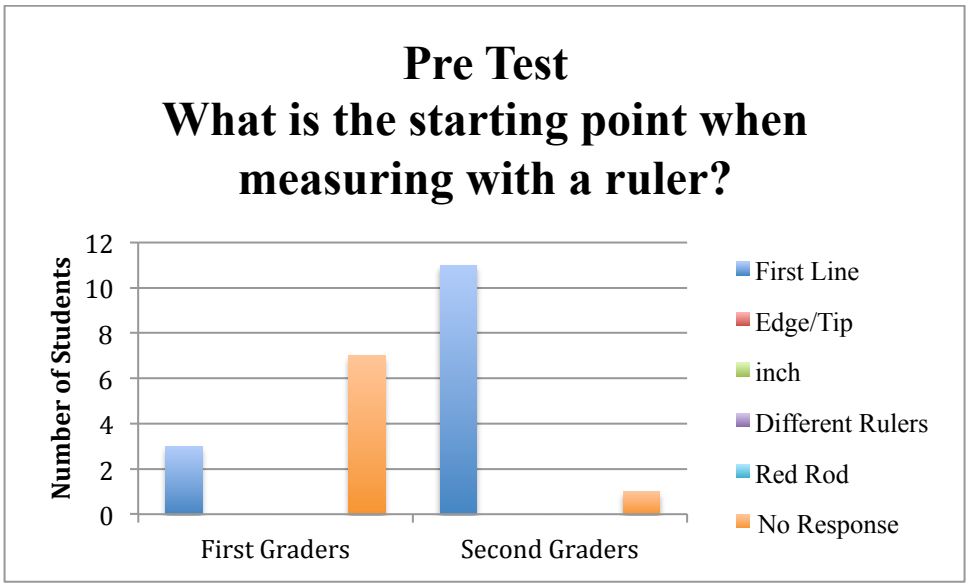
Analysis of Data

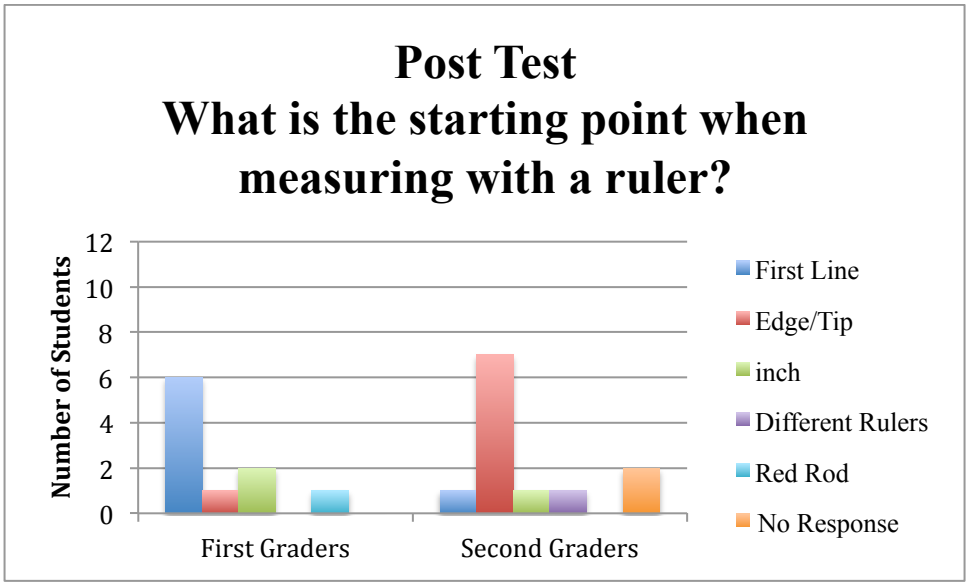
Research began by first asking students semi-structured questions (See Appendix D). Responses allowed for a base understanding of what the students knew before administering the pretest. During the semi-structured conference, many of the students were able to verbalize what it meant to measure and what standard and nonstandard tools were. Based on their responses, the pretest was administered on September 15, 2015.

The students exhibited difficulty with the test. It was decided to re-administer two days later. The questions were read out loud during group time. Students were allowed to draw their answers if they did not know the spelling and were able to circle the response to the questions that required one or another response. One second-grade student arrived late during the pretest and was not able to complete the pretest. This same student and another second-grade student were absent on the day of the post-test. Pre-Test: There were 10 first graders and 12 second-graders that were administered the pre-test.

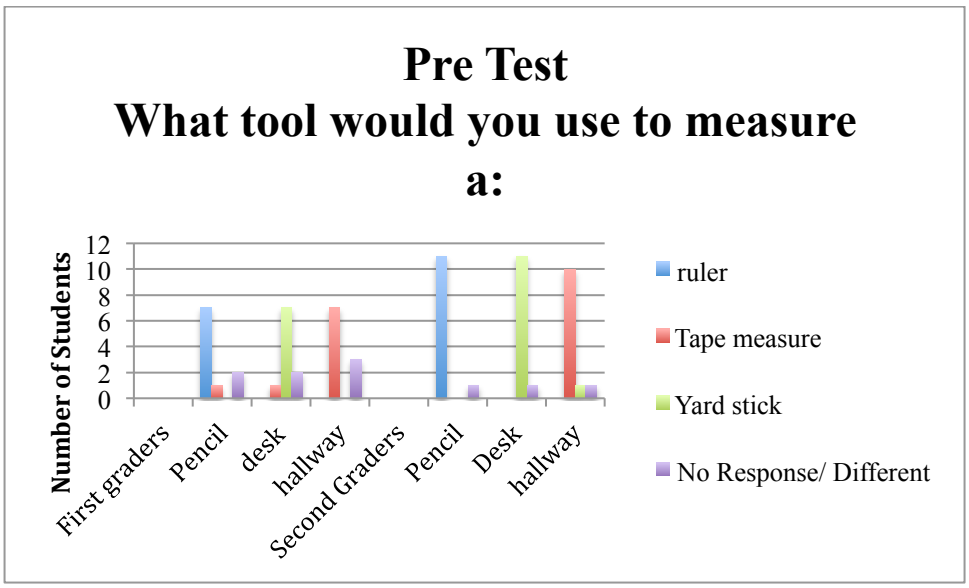
The responses to the questions on the pretest and post-test showed that measuring length is a difficult task for students in the first and second grade. First, when using a ruler, where to begin led to confusion. Different styles of rulers were used, some with the starting point on the edge, some with the starting point identified with a line near the end and one had a line marker that had “start here” labeled. The responses to the question “What is the starting point when measuring with a ruler?” lead to 3 first graders and 11 second graders identifying the “first line” as the starting point on the pretest and six first-graders and one-second grader on the post-test. The second graders responded more

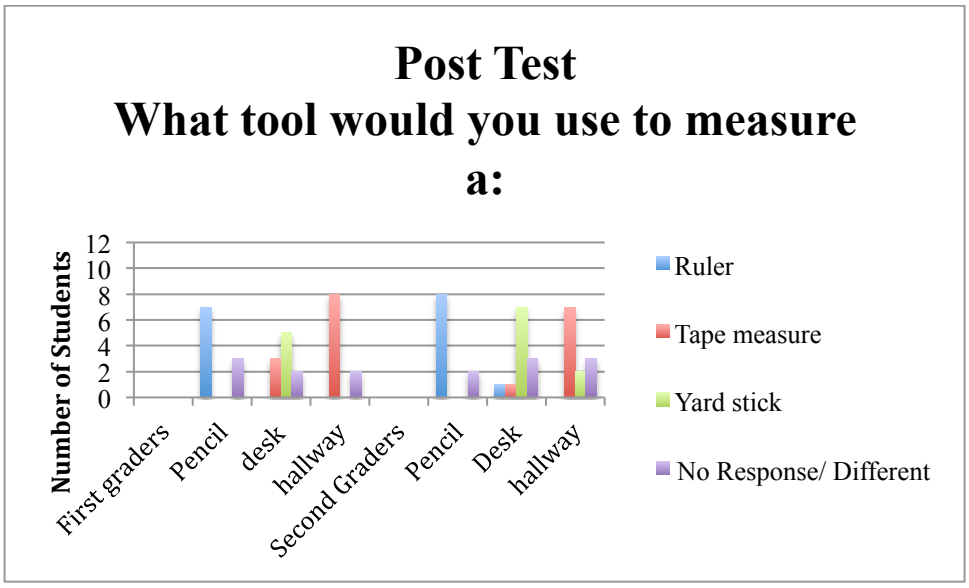
often on the post-test with the starting points beginning at the edge, tip or beginning of the ruler as the starting point.





Improvement occurred when the students were able to say what standard measurement tool would be used to measure a pencil, desk and hallway with customary units, such as inches, feet, and yards for the second graders, while the first graders responded the same for measuring a pencil, increased response in measuring a desk, one student less in measuring a hallway.



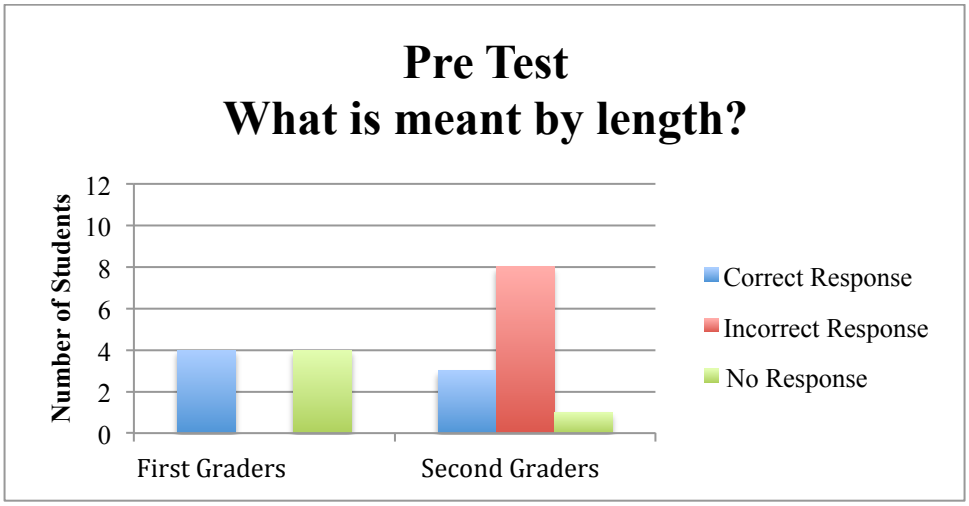


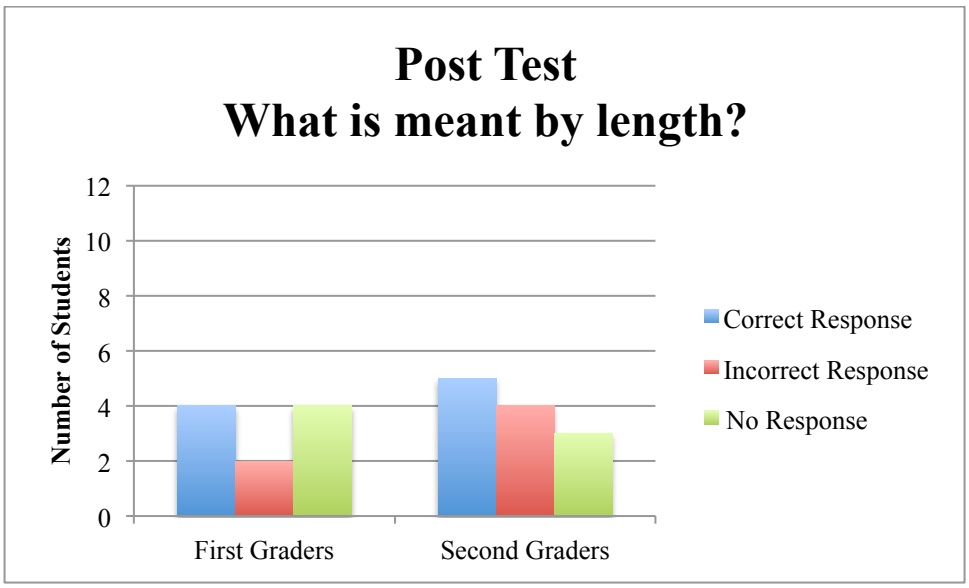
Knowing how many inches in a foot declined for both grades and how many feet in a yard improved for second graders. Students were less successful when it came to measuring using the metric system.

Students were asked to respond to "how many centimeters are in a meter"? No one got the correct answer. 7 out of the 22 students responded with ten as the number of centimeters in a meter, which leads me to believe that they were confused with 10 smallest red rods to equal the longest red rod.

The final question "How would you decide what to measure using inches or meters?" was a question that should have been removed from the tests, as it was too vague. Though, one second-grade student responded on the post-test "If you want to measure with customary units then you would use inches. If you want to measure with metric, then use meters". While another second grader showed her confusion with her response, "if it is small you use inches if it is big you will use meters". The answer to "how long it is" or "how big or small it is" was recorded by three first-graders and four second-graders on the post-test.

Overall, the responses to the questions on the tests showed that students in first and second grade lacked understanding of length measurement. The incorrect responses of the tests may have been due to the wording of the questions and the six-weeks between the pretest and post-test.





Data was collected through observational/field notes submitted by the two classroom teachers involved in the research. One teacher audio recorded several of her observations, which allowed her to observe and ask questions, and record exact wording. Additional materials were brought into the classroom for the students to use based on observations.

Materials added to the classroom included command cards from ETC Montessori Materials and Lakeshore Learning. Additional nonstandard materials such as linking clips, dinosaurs, foam feet, connecting worms, lima beans, and cotton swabs added interest to the measurement shelf. Students were also encouraged to use Montessori sensorial materials as measurement tools, such as the red rods, colored cylinders, and constructive triangles. The reading of different children's literature on length measurement also encouraged conversations and activity on how to measure and what tools can be used for measurement.

Standard measurement tools used were different types of rulers, wooden yardstick, paper measuring tape, and traditional tape measures. All of the standard

instruments had customary units (inches and feet) and metric units (centimeters and meters). The researcher was unable to locate a meter stick. Using the meter stick would have given more experiences with measuring in metric.

Students preferred measuring items with nonstandard tools. Measuring with the linking clips and foam feet were preferred. They often made relationships between using the linking clips being linked together and the links being put edge to edge. Students came to their conclusion that when laid edge to edge, the unlinked clips took more space. Linking the clips and keeping the links flat was easier. Edge to edge produced more overlapping and slanting of the clips. Students also compared the length of nonstandard tools with standard tools. One student reported, "one of us gets the links ruler, and one of us gets the paper ruler so we can measure things and make sure they are the same." Discussion about measuring with two different sizes of paper clips led one-second grade student to respond that you cannot measure with different sizes because, "wouldn't be even, one is smaller, and one is bigger."

When using standard tools, some students initially had a difficult time remembering what side of the ruler was metric and what side was customary. A second-grade student responded by stating "inches have more space" while another stated "centimeters have a littler [smaller] space, zero up to higher numbers, inches have more spaces and goes to 12 inches." Several students measured the blue line on the carpet. They began by using a tape measure, put the yardstick next to the edge of the tape measure then a 12-inch ruler, adding a 6-inch ruler and more 12-inch rulers. They then added the inches, beginning with 60 inches for the tape measure, and then adding inch by inch: 60, 61, 62, 63 up to 120 inches. One of the second graders said she had another

way to measure the line. She used a 12-inch ruler, marking her finger at the edge of the ruler, lifting it and placing it next to her finger each time. She did this 11 times. She wrote 12 x 11 but added 12 eleven times, coming up with 132 inches. A first-grade student measured five floor tiles with another first grader, keeping her on the edge of the ruler and telling her classmate where to place the ruler each time. The students were less likely to choose command cards unless they involved the connecting links, foam feet or connecting worms. Several students wanted to know if they had to use the command cards. Two said, "I just want to measure things." Children's literature was used to encourage discussion about length measurement.

After reading *Measuring Penny* and *How Big is a Foot*, students showed excitement in measuring with nonstandard tools. When asked why the bed was too small for the queen, from *How Big is a Foot,* one student responded, "Because the apprentice's feet are smaller than the king's."

The intent of this action research was to determine to what extent does the Montessori Mathematics curriculum support lower elementary Montessori students' understanding of length measurement. Students in both first and second grade had difficulties reading a standard measurement tool in both customary and metric units. Including the use of sensorial materials as nonstandard tools illustrates length both visually and tactically. Based on discussion with the two teachers assisting in gathering data, it is recommended that specific curriculum materials and experiences of measuring are required to improve students understanding of length measurement. The teachers will continue to spend focused time specifically in measuring length.

Action Plan

My action research showed that the Montessori Mathematics curriculum does support students understanding of length measurement when students are presented with key lessons and many opportunities to measure. The students utilized many different tools for measuring length. The tools they mainly chose were nonstandard, e.g. linking clips, paper clips, and foam feet. The students did use their own feet to measure objects, particularly after reading *How Big is a Foot*, but most enjoyed the novelty of the foam feet over their own.

The use of standard tools, e.g. rulers, yardsticks, and tape measures, were chosen when they needed to measure longer lengths or when requested by the teacher to use them. The reading of standard measurement tools was difficult for the students, which leads me to believe is why they primarily choose nonstandard tools.

For students to become comfortable with measuring length, I observed that they need to have many experiences measuring different objects with different nonstandard tools to have an understanding of unit iteration, conservation, and transitivity. When students were allowed to choose what they wanted to measure and what tools they wanted to use, conversations between each other about measurement increased. The conversations they had were important in their understanding of measurement and problem solving. Classmates would often interject their thoughts in another student's discussion.

Typically, the students' direct experiences with length measurement came from their math textbook. The students spent approximately one to two weeks on the concept before they moved on to a new concept. Having length measurement materials available

as part of the Montessori mathematics curriculum, and creating key lessons will encourage a better understanding of length measurement. On one of the days that we were discussing measurement, a second-grade student asked, “Do we have to measure today? I want to finish my work.” She did not understand that measuring objects is part of the curriculum. As a way to continue the students’ interest in measurement, I plan to keep encouraging the practice of measuring length as a part of their mathematics curriculum.

When students believe that measuring length is a part of the Montessori mathematics curriculum and is available during the work period, their level of understanding may increase. It is important for students to have core knowledge of length measurement for everyday life skills and higher education.

Variables that may have affected my results were the questions on the pretest and post-test due to the students reading skills and understanding of the terms. I would design the test with less open-ended questions and more graphics to help the students be more successful in completing the tests on their own. When preparing the tests to increase validity, I should have better identified the students reading abilities. I would have also had more available lessons requesting specific tasks to be accomplished for measuring.

The results of the research conducted on student learning recognized that students in lower elementary enjoy measuring different objects, each other, even their teachers. They showed more enthusiasm in measuring with nonstandard tools instead of standard tools. Teaching students how to read rulers, beginning with the placement of the ruler on the object to be measured is critical. One activity that the students did was to make their

own rulers. They used a standard ruler to place the inch marks on their paper ruler. Designing the ruler, placing them side-by-side and comparing the length to a tape measure led to a second-grade student's recognition of the relationship between the tape measure and time. She stated, "There are 60 minutes in an hour and 60 inches in the tape measure."

My intention is to continue researching how students learn length measurement by observing the students measuring with different measurement tools, including Montessori sensorial materials. Since the sensorial materials, e.g. red rods, and colored cylinders are designed in metric units, they may help support the students understanding of the metric system. I intend also to encourage the use of command cards, which are similar to command cards they use in the language arts curriculum in order to guide the students in having different experiences for measuring.

Overall, the research did show that Montessori lower elementary students can meet the requirements outlined in the California Common Core State Standards: Mathematics Measurement and Data Domain; specifically measuring length. Their ability to articulate their knowledge improved with their experiences. The responses to written questions did not reveal what they were able to express verbally, due to the wording of the questions.

Providing ample opportunities for students to work with multiple types of measurement tools and teacher prepared activities will hopefully lead to improvement of the lower elementary students understanding of length measurement utilizing the Montessori Mathematics curriculum.

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Appendix A

Pre/Post-Test

Students will be given a pre/post test with the following questions:

1. What is meant by length?

2. What tools can be used to determine the length of an object?

3. Name some nonstandard tools in measuring length.

    a. When using nonstandard tools, are the results a precise measurement or estimation?

    b. Do you get the same answer when measuring with different sizes of nonstandard tools?

4. Name some standard tools used in measuring length.

    a. When using standard tools, are the results a precise measurement or estimation?

    b. What is the starting point when measuring with a ruler?

5. What tool is best to use when a precise measurement is required, standard or nonstandard?

6. What tool would you use to measure:
    a. a pencil _____
    b. a desk_____
    c. the hallway_____

7. When using customary units, how many inches are in a foot?

8. When using customary units, how many feet or in a yard?

9. When using the metric system, how many centimeters are in a meter?

10. What are some things you can measure in centimeters?

11. When using the metric system, what would you use to measure:
    a. a pencil _____
    b. a desk_____
    c. the hallway_____

12. How would you decide what to measure using inches or meters?

Vocabulary students will need to know:

Customary units:
Inch unit is used to measure short lengths
Foot unit is used to measure longer lengths

International System of Units (SI) -Metric system
Centimeter is a unit to measure short lengths
Meter is a unit to measure longer lengths

Appendix B

Questions for Students Semi-structured Conference:

1. Please tell me what you know about measuring the length of something.

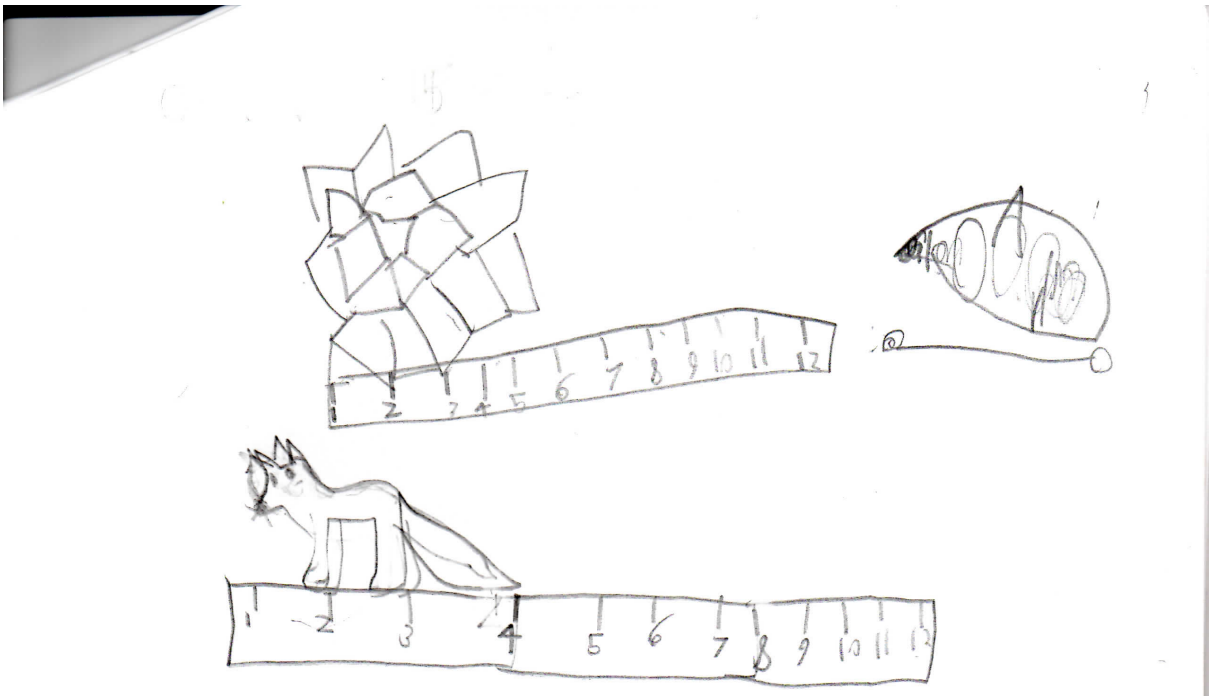
2. Please tell me what you know about measuring using customary units, such as inches and feet.

3. Please tell me what you know about measuring using the metric system, such as centimeters and meters.

4. Please tell me if there are any particular books you have had read to you or you have read that relate to measuring things.

Follow-up questions will be asked based on the students' responses.

Appendix C



The coyote toy is 4 inches. the cristal is 6 inches. the shell is 1 cotten swab

EWP.01

Appendix D